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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,457,456,** on February 11, 2004, by **JEAN-PIERRE LEPAGE,** for "System for Treating Contaminated Air or Gas".

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ABSTRACT OF THE DISCLOSURE

This invention relates to a method of sterilizing air that contains airborne pathogenic agents or microorganisms such as spores, bacteria, viruses, yeasts and mouldsThe method consists in damaging and braking up the contaminant molecular structure by oxidation and ionization and chemical bond rupture. Through this process the microorganisms or the contaminants are inactivated through structural damages to the cellular membrane and/or the nucleus membrane and/or to the DNA structure. This is accomplished by creating through the air to be treated, various electronic current having a plurality of specific controlled average kinetic energies matching the desired chemical bonds to be affected and/or ruptured. The air interaction with such various currents, having specific energies, sufficient intensities and exposition time is accomplished through several stages to completely sterilize the air or gas. The air or gas is then processed to remove undesirable by-products that may be present so that it can be used directly or stored.

SYSTEM FOR TREATING CONTAMINATED AIR OR GAS

BACKGROUND OF THE INVENTION

1 Field of the Invention

The present invention relates to air and other gas sterilization process.

2 Description of Prior Art

A number of patents (see,e.g.,U.S. Pat Nos. 6,245,132 , 6,664,741 B1 and EP1 194 175 B1) and other patents discussed below have recognized the fact that ionization produced by a set of electrodes may capture contaminant material in a fluid such as air and destroy to some extend certain living biological contaminants. These patents are based on the use of corona electrodes to generate ions and electrically charge the contaminants and then capture the contaminants on an attracting electrode. Other ones are using interaction with a flux of electrons and various absorbing materials to destroy or to sterilize the contaminants. These patents describe different types of electrodes such as wires, needle point, razor blade to form the emitting electrode. and flat or cylindrical attracting electrodes. None of these electrode and system descriptions or claims are using a three electrode set having on each of the electrode an arrangement of primary and secondary peaks where the electrodes are resonated at RF frequency to increase the AC current, and excited by a bipolar voltage waveform to create alternating positive and negative corona discharge currents each of these discharges having a specific electronic average energy level preferably matching the desired reaction energy level and thus avoiding the generation of undesired by-products.

In particular Pat No EP1 194 175 B1 dated 09-03-2003 and titled ``Method for treating a Gaseous medium containing contaminating particles`` is describing and claiming a method in which the fluid to be treated is accelerated to form a swirling air vein and made to interact with a first electron flux and then to have the ionized particles interacting with a second electron flux to transform the contaminant into gas. The fluid is then passing through a porous material where chemical reactions occur and where the contaminanted gas is transformed into non-toxic gas. Claim 1 and 2 are addressing the

destruction of the contaminant through the interaction of the fluid with an accelerated electron flux. Claim 7 of the patent specifies that the device incorporates some resonant magnetic cavities. No means to achieve such resonance are discussed nor described or claimed. Further more no specific means to first extract from the electrodes and secondly to generate an electron flux having specific electrons energy levels are discussed or claimed. No means not to generate undesirable by products such as ozone or NOx are addressed or claimed. The device is using a DC potential. No means to prevent arcing of the devices are discussed or claimed. No means to ensure the functionality of the device, which is critical for practical application, are either discussed or claimed. The presented invention relates to the air and contaminant interacting with an electronic current having specific mean energies to preferably rupture specific chemical bonds matching the electron energy .

In particular U.S. Pat. No 6,664,741 B1 dated Dec 16 2003 and titled ``Method of and apparatus for electrostatic fluid acceleration control of a fluid flow `` recognized that in order to increase the ions generation at the electrode it is advantageous to increase significantly the electrode AC current component. To achieve this the patent is using electrodes with a significant capacitance feed by a DC switching power supply having a relatively large ripple voltage component proving the AC voltage excitation to the electrode capacitance. The AC current generated being defined by the AC voltage of the ripple divided by the impedance of the electrode capacitance at the switching frequency. The AC current is thus proportional to that AC voltage and to the electrode capacitance at a specific switching frequency. The draw back is that the electrodes require a relatively large capacitance to generate any significant current to improve the efficiently considering also that the power supply switching frequency is also limited. Also the large AC voltage component superposed on the DC supply modulates to some extent the electron energies in the discharge. The patent has failed to recognize that a resonant electrode system, as claimed in the present Application, can achieve extremely high ac

current component by using a small ac voltage excitation even for a low capacitance electrode system.

U.S. Pat. No 6,245,132 dated June 12, 2001 and titled ``Air filter with combined enhanced collection efficiency and surface sterilization`` is using a basic filter that is sandwiched with two electrodes fed by a DC or AC or RF electrical source .The DC electrostatic field is used to attract the contaminant biological material, and intermittently a sterilization field using an AC or DC or RF source of enough intensity is applied to generate a surface plasma and thus destroying the contaminant biological material. No specific means for increasing the discharged current without increasing the electrical potential is claimed. In this patent the RF energy is used to sterilize directly where in the present patent application the RF resonance between the electrodes is used to extract the electrons. This patent does not make any claims with regards to an electronic current density having a controlled electrons energy level in the plasma to destroy the biological contaminants. Also no mention or claim is made to restrict the plasma energy level such that the plasma is not forming undesired by-products.

Patent No. EP0600101 dated 1994-06-08 and titled ``Device for biological cleaning and filtration of air`` is using corona discharging electrode and a non-discharging electrode to produce ions. The discharging electrode being a needle supplied with a large DC potential. Porous material is used in line of the airflow and an electrostatic precipitator is used to retain the contaminants. No means are claimed to provide an efficient current of particular electron energy level to destroy the contaminants or to control unwanted by-products.

Patent No. WO0249767 dated 2002-06-27and titled ``Electrostatic device for ionic air emission`` is recommending specific geometry of the receptive electrode, in a corona discharge system, to improve and make the collection of contaminants more

homogeneous over the electrode surface thus improving its efficiency. No specific means to control the ions energy generation or energy level are discussed.

U.S.Patent No 5,077,500 dated Dec. 13 1991 and titled `` Air transporting arrangement`` covers a specific geometry of the electrodes and the use of a dual power supply arrangement where one power supply control the ions generation and the second one their acceleration.This patent does not use or claim any resonant mechanism to generate the ions and does not address or claim any specific energy level not to generate undesirable by-products.

U.S.Patent No 6,504,308 B1 dated Jan. 7, 2003 and titled `` Electrostatic fluid accelerator`` covers some specific geometries of corona discharge accelerating and shielding electrodes to improve an electrostatic fluid accelerator.
Although is it mentioned on page 2, paragraph 60, that the invention: ``...will not produce substantial undesired ozone and nitrogen oxides when the fluid is air`` there are no specific claims on how to achieve this. Claim 4 in the patent makes reference strictly to a voltage setting within two extreme limits: ``a voltage between the said corona electrodes and said exciting electrodes is maintained between the corona on set voltage and the breakdown voltage``. In this patent in order to generate a significant amount of ions, an extremely large electrical field must be generated at the tip of the corona electrodes. This very large electrical field produces also high-energy particles that are susceptible to generate undesired by-products. A compromise is thus made between the quantity of ions generated and the production of undesired by-products.

SUMMARY OF THE INVENTION

The process described herein is used to treat air that may contain airborne biological contaminants that can be harmful if breathed by human and/or livestocks animals and or plants. The process is also applicable to treat air in close storage space where the food

may be contaminated by the air or by the release of by-products from the stored food , such as spores, decomposing products, maturating products, etc. In such condition the released by-products by the food may also contaminate the air.

The process breaks down large molecule contaminants into a large number of smaller segment molecules and is also capable of generating specific chemical reactions such as ozone generation.

The process is applicable to treat air in buildings, shelters and transportation means such as trains, buses, aircrafts, spacecrafts, submarines, boats and cars by processing the air circulating into their respective ventilation systems. By adding a means such as a ventilator to circulate the air through the system, the system may be used stand alone in an enclosure where the air needs to be treated. The process may also be used to treat air or gas that are needed to be stored in pressurized reservoir such as medical gas bottle and autonomous respiratory equipment for scuba diving, fire fighting, etc. The process is also applicable in the field of biological contamination protective suits and military gears where the existing filter on suit or mask may be replaced by or used in conjunction with the present invention.

The process also includes various means of monitoring that the device is effectively processing the air. This monitoring enables the operators or users to be warned in case of one or more malfunctions are detected. Since the device may be used in critical applications such as sterilizing hospital rooms, sterilizing the outside air used by military personnel in shelters or vehicles, etc the operation of monitoring of the system and the warning issues generated by the system are an integral part of the system and are very important functions.

The air to be treated is preferably but not limited to be processed at a pressure at which it is going to be used. The process may be performed at a pressure that is different from the

one that it is going to be used for example pressurized air for medical and dentistry equipments. The process is also self adaptable to air or gas pressure variation conditions encountered in, but not limited to, aircraft cabin pressurization, decompression chambers, etc.

The air is processed in four basic stages where the first two stages are used to break-up the contaminants as such, the third stage collects the by-products and the fourth stage neutralize the remaining undesirable by-products.

For stages one and two, a set of electrodes (2 or more) with a particular geometry, fed by a high voltage arbitrary voltage waveform, is used to create an electronic current density through the air. The electrodes are made to form an electrically resonant circuit that increases the ac current. At breathable or higher air pressure, the air density is relatively high and the electrons have the greatest mobility. Figure 1 shows the system using a 3 electrodes set.

The system uses positive and negative discharges, alternating over time, each current discharge being formed by a specific voltage polarity and amplitude duration to achieve the desired effects on the contaminants. The polarity of the voltage excitation on the electrodes determines the type of corona discharge current that is generated at the tips of the electrodes.

The specific geometry at the electrode tip increases locally the electrical field such that the discharge can be sustained. By controlling the voltage between the electrodes the electrical field at the electrode tips is well controlled. The established electrical field is the key to control the effective electrons energy distribution.

The physics of positive and negative corona currents are very different. This asymmetry is the result of the large mass difference between the electrons and the positive ions. At

room temperature and pressure the electrons have the ability to undergo a significant degree of ionizing non elastic collision. The mechanisms involve in both positive and negative corona current discharges rely on the strong electrical field at the tip of the electrode, that once a neutral molecule is ionized (by a natural occurrence), the electron and the ion are accelerated in opposite direction and prevent their recombination while imparting them with kinetic energy.

Due to their small mass the electrical field accelerates the electrons more acutely and more positive ion and electron pair are thus generated by collisions between electron and neutral molecule. These new ions and electrons undergo the same separation process and an avalanche of electrons is generated. The process can be maintained if a secondary source of electrons exists to create a steady discharge current. The dominant mechanism for the creation of the secondary electrons depends on the polarity of the discharge. The energy emitted as photons by the initial avalanche is used to ionize a molecule creating another accelerated electron for both polarity of discharge, the difference residing in the source of these secondary electrons.

For positive discharge cycle the electrons are concentrated close to the tip surface of the electrode where a large electrical field exist. This inner region is the plasma region. There is much fewer free electron in a positive discharge except close by the tips when compared with a negative discharge . The electrons in a positive discharge have a large kinetic energy and thus are more suited for high activation energy reactions. The flow of positive ions toward the receptive electrode possesses a low kinetic energy and this form the outer or unipolar region. All the secondary electrons are generated by photons ionization.

For the negative discharge cycle the electrons are allowed to drift out of the ionizing region of the electrode tips such that the plasma continues some distance from the tips. The total number of electrons is much greater than in the positive corona except that the

electrons have predominantly a much lower kinetic energy when compared with the positive corona. For negative corona the dominant process to generate secondary electrons is the photoelectric process that is taking place at the electrode tip surface itself. The work-function of the electrode tip being much lower than the photon enery generated by of the electron ionization with neutral, the secondary electrons are thus emitted from the tip surface through this process. The use of ionized neutral gas as a source of ionization is further diminished in a negative discharge by the high concentration of positive ions cloud around the electrode tip. The collision of these ions with the electrode tip may also contribute to the secondary electron liberation.

The stability of the negative current discharge is sustained with electronegative molecules present in the air such as oxygen and water vapor that capture easily free electrons in the outer region of the discharge and prevent the electrons from creating a narrow current channel developing into a spark. The negative discharge thus generates lower electron energies when compared to the positive discharge and is suitable for low activation energy reactions.

For both polarities of corona discharge it as been established that the electrical field is not modified significantly by the presence of the discharge due to the relatively low-density space charge distribution. Although the electron energy distribution deviates from a Maxwellian distribution, the actual high-end energy population being slightly lower, it is useful to approximate the actual electron kinetic energy distribution to a Maxellian one and use the mean energy of the distribution as a function of the electrode peak electrical field. In such a case the mean electron kinetic energy (Umean) depends solely on the electrical field strength .

For positive discharge and an electrical field strength between 9.0E6 and 3.0E7 V/m the mean electron kinetic energy is given by: Umean (eV) = 5E-7 * Et + 3.035 where Et is

the electrical field in V/m at the electrode tip. For field strength between 3E6 and 9E6 V/m the mean electron kinetic energy is given by Umean (eV) = 4.137 ln(Et) – 58.555.

Under these conditions and discharge mechanisms, through the electrical field (Et) intensity and polarity present at the electrode tip, the electrons acquire a controlled average kinetic energy so that when they collide with a molecular structure they break-up or rupture preferably specific chemical energy bonds matching the electron energy.

The present invention uses these key processes to achieve the destruction of the contaminant.

The electrical field polarity and strength is controlled independently for positive and negative discharges by controlling the potential between the electrodes.

For a positive discharge cycle the peak voltage controls the high-energy electrons suitable to rupture high-energy liaisons. The voltage being limited not to favor high energy reactions forming undesired by-products where for the negative discharge cycle the peak voltage is controlled to be above a minimal value such that low energy reaction will not favor the formation of undesirable by-products.

The overall interaction with the air produces ionized molecules, ionized atoms, free specific mean kinetic energy electrons, photons and chemical bond rupture. The net result is that the large molecular structures are broken down into several smaller segments.
The electrons and ions through interaction with the gas forming the air and the contaminant itself generate energetic photons that will bombard the contaminant and help creating ionization and breakdown of hydrogen bonds and damage to the nucleic proteins. The breakdown occurs on the contaminants by rupturing hydrogen bonds and creating oxidation of the protein membrane of the contaminant.

The three electrodes structure has another advantage for stage 1 and 2. Since the inner electrode is virtual, i.e. highly transparent with respect to the air flow but having an electrical field of opposed direction on each of its side, this create an ions trap and thus increases their exposition time to the photons and electrons instead of being neutralized right away at the electrode surface. For positive polarity of the inner electrode the negative ions are trapped. For negative polarity the positive ions are trapped.

Energetic photons are also generated in stage 1and 2 when the exited molecules return to their basic states. In stage 2 these photons are reflected back and forth between the reflective outer electrodes due to fact that the central electrode is highly transparent (mesh, largely perforated sheet metal or wires). This feature increases the chance that these photons will ionize more material and will create, by photon energy absorption, damages and structural breakup of the contaminant biological constituent.

Stage 3 provides a DC electrical field having a large spatial gradient between the electrodes that will attract, on the electrode surfaces, the ionized contaminants and others ions still present in the air.
The electrical field gradient will also attract neutral contaminant particles using the intrinsic electrical dielectric moment of the particles.

Stage 4 provides a means to neutralize any ions by returning the electrical charges to ground. It also acts as a catalytic converter to remove for example ozone or others undesirable by-products in certain air or gas treatment applications.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates schematically, by the way of example, the system diagram of the preferred embodiment of the invention comprising the four basic processing stages.

FIGURE 1a illustrates schematically, by the way of example, the cut view A of the system diagram presented in figure 1.

FIGURE 1b illustrates schematically, by the way of example, the cut view B of the system diagram presented in figure 1.

FIGURE 1c illustrates schematically, by the way of example, the cut view C of the system diagram presented in figure 1.

FIGURE 1d illustrates schematically, by the way of example, the embodiment for the electrode interconnections of stage 1A.

FIGURE 2 illustrates schematically, by the way of example, an embodiment for the electrodes and peaks geometry used for stage 1 (1A).

FIGURE 2a illustrates schematically, by the way of example, an embodiment for the electrodes and peaks geometry used for stage 2.

FIGURE 3 illustrates schematically, by the way of example, a typical high voltage arbitrary waveform with the control parameters T1 to T8 for the duration and V1-V2 for the amplitude of the positive and negative cycle respectively.

FIGURE 3a illustrates schematically, by the way of example, the electrodes electrical model forming a resonant series circuit with the impedance network and the excitation supplied by the high voltage arbitrary waveform and alternate excitation means..

FIGURE 3b illustrates schematically, by the way of example, the electrodes electrical model forming a resonant parallel circuit with the impedance network and the excitation supplied by the high voltage arbitrary waveform and alternate excitation means.

FIGURE 4 illustrates schematically, by the way of example, the electrodes using a planar geometry for stage1.

FIGURE 4a illustrates schematically, by the way of example, the electrodes using a planar geometry for stage 2.

FIGURE 5 illustrates schematically, by the way of example, the electrodes using a cylindrical geometry.

FIGURE 6 illustrates schematically, by the way of example, the stacking of multiple electrodes using planar geometry to increase the device capacity.

FIGURE 7 illustrates schematically, by the way of example, the stacking of multiple electrodes using cylindrical geometry to increase the device capacity.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 presents a system representation of a preferred embodiment of the invention.

The air enters through an incoming duct adapter (1). A blower or compressor (28) may be used to push the air through the system and/or to compensate for the pressure drop across the system.

The air is then processed by a filter (2) that removes large size particles present in the air such as fibers, dust particles, etc.

The air then passes through a device (3) that makes the airflow slightly turbulent and also directs the airflow towards the first stage electrodes. The device (3) has a funnel shape

perforated with holes of different diameters and shapes. Its geometry may be triangular, pyramidal or conical depending on the duct cross-section shape. It also has directing vanes or flow directors (3a) (shown partially for clarity) to force the airflow to pass within the electrodes of the corresponding stage.

This funnel provides a good air mix and ensures that the contaminated air will be slightly turbulent and will pass within the electrodes with a non-zero vertical speed such that the air will be fully exposed to the electronic current. Other flow directors (3a) (shown partially for clarity), between the stages, ensure that the airflow is directed between the electrodes.

The air then passes through four basic stages of processing. The total number of stages may be increased by repeating one or more particular stages. The order of the stages and their distributed respective numbers may also be modified to achieve a desired specific processing.

STAGE 1

This stage uses a basic set of three electrodes.
The outer electrodes (4) and (6) are connected together and to one terminal of an high voltage waveform1 provided by a controller (7). The inner electrode (5) is connected through an impedance network Z1 (8) to the other terminal of the corresponding high voltage waveform1 (7). These electrodes (4)-(5)-(6) are all made of conductive material and are transparent with regards to the airflow. The electrode surfaces are all placed perpendicular to the airflow. We may also refer to these electrodes as being *virtual* electrodes in the sense that they are conductive and they define an electric field along the airflow over the whole cross section surface but at the same time they do not restrict or block the airflow. The electrodes can be made from wire grid or mesh, parallel wires or perforated sheet metal providing open spaces for the air to flow. These electrodes are

coated or plated with high electronic emissive material to ease electrons generation (extraction). These electrodes are also processed in such a way that the surfaces are not smooth but covered with peaks (14) that increase the local electric field at their top edge and thus enhance the electron generation (extraction). The peaks may take various shapes and are of, preferably but not limited to, triangular, square, rectangular and polygonal, shapes. The exposed edges of these peaks also have secondary peaks along their exposed sides. The peak edges are made sharp. The peaks on each electrode are arranged in such a way that each peak is not facing directly another peak on the opposite electrode. Preferably but not limited to the peaks on one electrode, a collection of peaks faces the opposite electrode and this pattern is repeated alternatively between two electrodes. See figure 2 and 2a for examples of the preferred embodiment for the peaks arrangement. The inner electrode and the outer electrodes are forming an intrinsic electrical capacitance designated as Cstage1.

STAGE 1A

Another embodiment of stage 1 is stage 1A presented in figure 1d that uses different electrode interconnections. The electrode (4) this time is connected to the impedance matching network Z1A (8) and electrode (5) to the other terminal of the high voltage waveform1A. The electrode (6) is this time connected to a large DC voltage supply (8a) and the other side of the DC supply is connected to electrode (5). The waveform1A is now restricted to negative polarity and the DC supply polarity being positive with respect to electrode (6). Electrode (4) and (5) have peaks as described above in stage 1 but strictly limited to the space facing each other. Electrode (6) has smooth surfaces and is a virtual electrode used strictly to accelerate the ions generated between electrodes (4) and (5). Alternatively the polarities of the voltage waveform1A and the DC supply may be inverted together. Under this particular stage 1A electrodes configuration the generated ions passing through the virtual electrode (5) are pick up and continue to be accelerated by the large DC field between electrode (5) and (6) until they become neutral. These ions

through multiple collisions with neutral molecules and atoms impel a net force on the air mass within the electrodes. The net result is that these multiple directed collisions are effectively moving the air through the system from the left to the right with reference to figure 1d. This particular stage 1A configuration enables the air to be processed without the need of an external air blower or circulator for a stand-alone application.

STAGE 2

This stage uses a set of three electrodes.
The inner electrode (11) of stage 2 is similar to the central electrode described in stage 1 except that the electrodes surfaces are placed parallel to the airflow and the peaks have a limited orientation. The central electrode (11) is connected this time through an impedance network Z2 (13) to one terminal of high voltage waveform2 of the controller (7). The opposite side of the impedance network is connected to the high voltage waveform2 of the controller (7). The outer electrodes (9) and (10) are this time continuous (not virtual) and are also conductive and preferably reflective to light. The outer electrodes (9) and (10) are electrically connected together and connected to the other corresponding terminal of the high voltage waveform2 operating with a different set of parameters provided by the controller (7). These electrodes are also processed in such a way that the surfaces are not smooth but covered with peaks (14) that increase the local electric field at their top edge and thus enhance the electron generation (extraction). The peaks may take various shapes and are of, preferably but not limited to, triangular, square, rectangular and polygonal, shapes. The exposed edges of these peaks may also have secondary peaks along their exposed sides. The edges are made sharps. The peaks on each electrode are arranged in such a way that each peak is not facing directly another peak on the opposite electrode. Preferably but not limited to the peaks on one electrode is facing a collection of peaks on the opposite electrode and this pattern is repeated alternatively between two electrodes. These electrodes are coated or plated with high electronic emissive material to ease electrons generation. The peaks orientation is limited

to peaks that are aligned with the airflow such that they do not restrict the airflow significantly. The peak arrangement between the inner electrode and the outer electrodes are forming a staggered distribution. The inner and the two outer electrodes are forming an intrinsic electrical capacitance designated as Cstage2. On the drawing the electrodes spacing is exaggerated.

This section is continuing the breakup of the contaminants using a different excitation voltage waveform that is more appropriate to deal now with smaller contaminant size. This section also provides ionization of the remaining broken-up contaminants to be handled by the third stage.

Preferably, for stage 1 and stage 2, the outer electrodes (4 and 6) and (9 and 10) respectively may be are referenced to earth ground for protection. The central electrodes (5) and (11 may alternatively be referenced to earth ground. In this later case, electrical insulation is required on the outer electrodes for protection against shock hazard.

In general for stage 1 and 2, the outer electrodes and the inner electrode are spaced by a distance d in the order of a fraction to few centimeters with waveform amplitude applied to the electrodes in the order of few Kilovolts. The intrinsic electrical field determines the average kinetic energy of the free electrons. The specific energy of the free electrons generated is the key to control the breaking up process and the undesired by-products generation.

RESONANT ELECTRODE SYSTEM

For stage 1 (1A) and stage 2, to enhance the electronic current generation thus the electrons extraction, this invention uses a novel approach that resonates the electrode AC current component.

The electric current flowing between the inner and outers electrodes may be broken down to two components: the first one is the DC current component generated by the DC voltage component on the electrodes. That current is extremely small due to the very high resistance of the air. The other one is the AC current component, which is due to the AC voltage component between the electrodes. That AC current is proportional to the electrode capacitance and the electrode AC voltage component.

We may write using the Ohm law: Iac = Vac * Wac * Cstage where the Iac is the current AC component in Ampere between the electrodes, Vac is the AC voltage component across the electrodes in Volt, Wac is the pulsating frequency of Vac in radian per second and Cstage is the capacitance in Farad of the electrodes for a given specific stage the capacitance is determined by the geometry of the electrodes and is on the order of few pico-Farad. Previous patents try to maximize this capacitance in order to increase the AC current. This approach leads to complex electrode geometry with tight dimendional tolerances. In order to increase that AC current we can increase the Vac and or the Wac. Since we cannot increase the Vac voltage above a certain threshold otherwise too high energy electrons will be generated and consequently undesirable by-products will be formed so it seems that we are limited to increase the frequency . Producing very high voltage at high frequency (megahertzs) is not a simple affair. A novel alternative is proposed here that is to lower the effective impedance presented by Cstage of the electrodes by using, in series with the inner electrode and the voltage waveform, an inductive impedance Lstage that will resonate with the electrodes capacitance at a frequency Wac = SQRT (1/Lstage*Cstage). Strictly speaking the resonant frequency is slightly shift downward due to some resistive component part of the circuit. Figure 3a provides a schematic representation of the embodiment. For the purpose of explaining the principle, we consider that Wac as given above is a close approximation of the resonant frequency. At the resonant frequency Wac, the combined impedance of the electrode capacitance Cstage in series with the inductance Lstage becomes extremely small such that the AC current increases drastically even for a very low excitation voltage (high Q

factor of the resonant circuit). The excitation voltage at the resonant frequency Wac may be supplied by the high frequency component spectrum content of the relatively low frequency main high voltage waveform. Alternatively a high frequency very low voltage signal source having a frequency Wac may be superposed on the main high voltage waveform by using a small coupling capacitor or a transformer in series with the central electrode terminal. The electrode resonant circuit may also be coupled to a small amplifier feedback path to form an oscillator that uses the electrode resonant circuit as the tuning element. It is also important to note that the intrinsic current noise of the DC discharge itself that is very rich in high frequency components (wide band noise source) will excite the resonant circuit and will have a natural tendency to resonate the ac current component at frequency around Wac.

Consequently the imaginary part of the network Z1 (8) and Z2 (13) shall be selected to be highly inductive around Wac with a value such that it will resonate with the corresponding capacitance Cstage 1 formed by the electrodes (4-5-6) and Cstage 2 formed by the electrodes (9-10-11) at the desired frequencies Wac1 and Wac2 respectively. A small coupling or de-coupling capacitor, depending on the preferred implementation, on the order of ten times the Cstage capacitance is used to close the resonant circuit. Alternatively the electrode capacitance may be resonated in parallel mode. Figure 3 b provides a schematic representation of this particular embodiment.

HIGH VOLTAGE WAVEFORM

The controller (7) supply different high voltage sources having their amplitudes and polarities that are controlled over time to make a specific voltage waveform for each particular air processing stage. The controller (7) is powered by and external power source (27). The voltage waveform is an arbitrary AC voltage waveform having a specific amplitudes repetition pattern with controlled rise and fall time, on and off time

periods and possibly DC offset voltage component. These controlled waveform parameters are very important for the following reasons:

The rise and fall times of the main voltage waveform need to be controlled in absolute value in order to restrict undesirable ionization energy level and or avalanche condition between the electrodes. The positive and negative voltage amplitudes are controlling the desirable energy level of the electrons. The alternating voltage polarity provides positive and negative coronas with their respective electron energy distribution. The on time of the waveform either positive or negative controls the contaminants exposition time. The off time provides a mean to extinguish possible arcing situation. The repetition rate may also be preferably selected to be an acoustical resonance mode of the cavity formed by the electrodes to generate resonant phonons thus improving the system reactivity.

STAGE 3

The outer electrodes (16) and (17) are connected together and to one terminal of an high voltage waveform3 provided by a controller (7). The inner or central electrode (15) is connected through an impedance network Z3 (18) to the other terminal of the corresponding high voltage waveform3 (7). The electrodes composing stage3 are conductive and free of any peaks. These electrodes are arranged in such a way that the electrical field generated between the electrodes is not constant over the spacing distance but has a gradient. For example, to achieve this field gradient the effective surface of central electrode (15) shall be significantly smaller than the surface of the outer electrodes. These electrodes are preferably enclosed in a slightly leaky dielectric to dissipate the ions electrical charges. The high voltage waveform3 has preferably a very high DC content. The impedance network Z3 (18) is this case provides a protection to limit the current feeding the electrodes in case of a malfunction.

The role of this section is to capture the remaining charged particles and by-products that are present in the air. The dielectric coating effectively increases the electric field within the electrode spacing. The negative electrode will attract the positively charged particles and the positive electrode will attract the negatively charged particles. The electrode geometry is also selected such that the electric field is not constant within the spacing but has preferably a gradient to attract neutral particles. Certain neutral particles will be attracted on the surfaces due to their inherent electric dipole moment interacting with the electrical field gradient. The surface of the dielectric exposed to the air shall be preferably of a rough finish so that the attracted particles are captured by the surface. The electrode surfaces may also be made porous and coated with a chemical substance that will react with the undesired by-products and neutralize them. This section shall also be built in such a way that the electrodes are easily accessible for cleaning or replacement. The planar and cylindrical geometry are the preferred embodiment for stage 3.

STAGE 4

Once the air flowing through the device gets fully sterilized over stage 1-2-3, the air penetrates into a fourth section where the remaining ions still present are neutralized. This neutralizer is composed of a series of staggered wires (19), isolated from each others, or fine wire mesh that are electrically grounded to earth, So that any remaining charged particles are neutralized. The wires or the mesh may be coated with a catalytic material that produce breakdown of ozone that may be present in small quantity after the process. To improve efficiency, the wires or the metal mesh may also have an electric current generated by the controller (7) circulating through it to heat by Joule effect and increase the wires or mesh temperature thus improving the catalytic conversion process.

CONTROLLER

The controller (7) generates the various voltage waveforms for the different stages. The controller reads the air pressure (20) and temperature (23) in the sterilizer volume and controls, for each stage, the voltage waveformsWSn using a control law for example but not limited to:

WSn applied = (WSn0 at P0 and T0) X ((Pactual X T0) / (Tacual X P0))^K .
Where Wsn0 is the voltage waveform at P0 and T0 for stage n, P0 is the sea level reference Pressure, T0 is the sea level reference Temperature, Pactual is the measured air operating pressure, Tactual is the measured air operating temperature , WSn is the applied voltage waveform to the electrodes corresponding stage n and where K is an exponent normally equal or close to one when the ratio of Pactual T0/TactalP0 is between 0.84 and 1.16.. For ratio outside that range K takes other values.

The controller interfaces with photo detectors (21 and 22) that are sensitive to the light radiation emitted by the plasma within the electrodes of stage 1 and 2. The level of the detected light is used to verify that the actual sterilization is taking place and consequently that the sterilizer operates properly. If un-proper level of light emitted by the plasma is detected, the controller (7) issues a warning (25) to the operators or the users.

The photo detectors (21 and 22) may be composed of a plurality of detectors/filters, each of these detectors/filters being sensitive to a different specific light wavelength band corresponding to a specific ionization or rupture energy of a chemical reaction.

The controller (7) reads each wavelength band intensity. The controller then compensates for the different optical filter losses and detector sensitivities to produce a histogram of the photoemission spectrum of the plasma within the electrodes. The controller then imposes criteria's on the intensity of each band to produce a valid signal

meaning that the sterilizer is operational. The criteria may be simply, but not limited to, the presence of a minimum level of a particular band or a group of bands and or the absence above a maximum level of another band or another group of band.

The controller reads the differential air pressure (24) between the entry and the exit of the system. This pressure difference is related to the flow of air through the system and is used to provide operators/users feedback on the quantity of air processed. When a too low-pressure drop condition is detected between the entry and the exit of the system, an warning indication is provided that not enough airflow is circulating through the system. If a too high-pressure drop is detected this is an indication that the airflow capacity of the system is exceeded or that the system is clogged. In all the above cases, a warning (25) shall be issued to the operators or users.

The controller (7) reads the electrode currents for the various stages. These measurements enable the controller to verify that the device is operating within proper preset parameters based on the operating voltage. This feature is used to issue a malfunction warning (25) to the operator in the case that an out of limits current is detected. A too high current may be an indication that the system is dirty and that stray conduction paths may exist or that an arc may be actually taking place. A too low current may be an indication that the plasma is not forming within the electrodes and that the sterilization is not taking place.

The high voltage supply at the electrode for each stage may also be monitored to be within certain preset value in conjunction with the others parameters described above in order to determine the proper operation of the system, and issue a warning (25) to the operates or users in case of a malfunction. The voltage and the current readings may also be useful to diagnose a system failure.

The inner electrodes of the first three stages are feed by the corresponding voltage waveform using in series a current limiting device Z1-2-3 (8), (13) and (18). These impedance networks beside providing an inductive component to resonate stage 1 and stage 2 (and 2A) are also used to prevent possible arc formation between the central and the outer electrodes. During an arc, the electric current would increase drastically and the limiter device would drop the electrode voltage thus preventing the arc to continue. Current limiting devices may be passive such as resistor or inductor or may be active electronic circuits or a combination of both. The current limiting function is part of the impedance network, which is also used to resonate the RF excitation current for stage 1-2. Figure 3a present one possible arrangement of the network impedance that combines the Cstage1or2 capacitance resonance function and the current limiting function to prevent arc formation.

The high voltage arbitrary waveform may also incorporate an off period of time. The off time being sufficiently long to extinguish the current carriers if an arc is formed.

The basic frequency of the high voltage arbitrary waveform can be preferably selected, in relation with the electrodes geometry (spacing width and length) and the nominal operating temperature, such that resonant phonons are established within the system thus improving its efficiency.

The basic planar geometry for stage 2 (figure 4) may also be modified to form a cylindrical electrode geometry (see figure 5).

To improve the device capacity to process large air flows, the electrode geometry may be repeated to form a stack of electrodes. This increases the cross section of the system and maintain the exposition time of the contaminants. This stacking of electrodes is applicable to the planar geometry (see figure 6) and to the cylindrical geometry (see figure 7).

Claims

1. A system to sterilize air or gases or a mixture thereof containing airborne pathogenic agents or microorganism or contaminants by exposing the contaminated air or gases or mixture thereof to be processed to a succession of stages of electronic currents passing through the air, gases or mixture thereof and interacting therewith, each of these stage currents having a specific controlled average electronic kinetic energy preferably matching the desired chemical energy bond to be ruptured and where the contaminants are progressively destroyed from stage to stage by breaking-up their whole molecular structures into smaller molecular segments; said contaminants being also damaged such that their deoxyribonucleic Acids (DNA) integrity and/or their cellular and/or their nucleus membrane structures are affected thus preventing said contaminants from infecting an host.

2. A device as described in claim 1 that can process air or a gas or a mixture thereof at pressure above or below atmospheric pressure by automatically sensing the operating conditions, such as the pressure and temperature and adjusting the control parameters such as the voltage or the current waveforms producing the electrical field at the tip of the electrodes that control the free electrons energy distribution.

3. A device as described in claim 1 which incorporates means to verify that the desired specific conditions to perform the sterilization are effectively achieved and one or more warnings are generated to the users or the operators when one or more malfunctions and/or abnormal conditions are detected.

4. A device as described in claim 1 wherein:

- the specific stages, each having an electronic current density with a specific controlled average kinetic energy, are generated inside a set of three electrodes, said set of three electrodes having a particular geometry and being formed with two outer

electrodes electrically connected together and one inner electrode placed between the two outer ones,

- said set of three electrodes forming a connection with two terminals and such set being placed across and/or through the air flow;
- said connections with two terminals being connected and supplied by an arbitrary high voltage or current waveform source provided by a controller;
- the electrodes exposed surfaces being fitted with numerous conductive ``peaks``, electrically connected with the electrodes, and distributed over the electrode surfaces to provide a controlled high electric field at their tips when supplied by an arbitrary voltage waveform;
- said arbitrary voltage waveform creating a specific electric field, having a specific strength at the electrode peaks for each polarity of the arbitrary waveform and providing the desired specific average electron energy levels preferably matching the energy levels of the contaminant molecular bonds to be ruptured or damaged either by electron collisions or photons generated by electrons ionization activity;
- the electrodes peaks exposed surfaces being preferably made of, or coated with, or plated with, metal having specific electron extraction energy;
- the inner electrode being transparent with regard to the air flow and creating an ions trap within its openings due to the opposite electrical field direction on each side of the inner electrode, thus preventing the ionized contaminants neutralization and improving their exposition time to the photons and electrons bombardment.

5. A device as described in claim 4 where the electrode set is composed of two electrodes; one inner electrode and one outer electrode.

6. A device as described in claim 4 where the sets of electrodes are composed of at least one set of three electrodes and one or more added sets of two electrodes where all the inner electrodes are electrically connected together and all the outer electrodes are

electrically connected together and forming together a capacitance set with two terminals having 1+N inner electrodes and 2+N outer electrodes where N is the number of added sets of two electrodes , N taking integer values greater or equal to zero.

7. The device of claim 6 wherein said capacitance set with two terminal electrodes resonates at RF frequency with an impedance network in series to provide an RF electrical field between the electrodes superposed over the main electrical field provided by the arbitrary voltage waveform.

8. The device of claim 1 that is composed of several processing stages wherein

- each of such stages having a specific electronic current density and average energy, are placed in succession in the air flow path to produce a selective and progressive breakdown of the biological contaminants by ionizing, oxidizing and rupturing chemical bonds of the contaminant biological structure; and
- -each successive electronic current stage is breaking up the contaminant molecular structure into smaller and smaller molecular segments.

9. The device as described in claim 8 wherein

- for each stage, a specific set of electrodes having a specific geometry is connected to a specific high voltage or current waveform generated by a common controller and create between the electrodes a specific electrical field, and
- -the free electrons at the electrode tips , under the influence of the high conrolled electric field, acquire a controlled average specific kinetic energy so that when the electrons collide with the contaminant molecular structures they break-up, ionize and rupture preferably specific chemical bonds having an energy matching the specific average electron energy and where the ionized neutral molecules by the electrons generate high energy photon that bombard the contaminant.

10. The device as described in claim 9 wherein the sets of electrodes of each stage are interconnected to form a two terminal connection being connected to the controller high voltage or current waveform generator and wherein at least one such terminal is connected in series with an impedance network.

11. The device of claim 10 wherein said impedance network has at least but is not limited to a first inductor and a first resistor in series connected to the electrode to provide a resonant electrode function and wherein said impedance network has also but is not limited to a second inductor and resistor in series providing a current limiting function and connected in series with said first resistor and said first inductor.

12. The device of claim 11 which incorporates a resonance function wherein each electrode set is forming a specific capacitance and wherein that capacitance is being resonated at radio frequency with the first mentioned inductor in series with the first resistor to increase the AC current at radio frequency within the electrodes, thus improving the electrons excitation and wherein said first resistor is controlling the quality factor of the resonant circuit.

13. The device of claim 12 wherein the impedance network is made to resonate with the electrode capacitance wherein the resonant circuit is excited by the high frequency components of the voltage or current waveform creating the electrical field., and where a decoupling capacitor with a value being of the order of but not limited to 10 times the electrode set capacitance, is placed across the second resistor and second inductor in series to complete the resonant circuit.

14. The device as described in claim 12 wherein the impedance network is made to resonate with the electrode capacitance wherein the resonant circuit is excited by an RF source coupled through a capacitor and connected to the common point formed between the first resistor and inductor circuit and the second resistor and inductor circuit and

wherein said coupling capacitor value is of the order of but not limited to 10 times the electrode set capacitance and wherein the other terminal of the RF source is returned to ground or to the outer electrode, the impedance of the said second inductor and resistor in series being large enough at resonant frequency not to load significantly the RF source.

15. The device as described in claim 12 wherein the impedance network is made to resonate with the electrode capacitance where the resonant circuit is excited by an RF source through a transformer where the secondary of the said transformer is connected in series with the voltage or current waveform and wherein the primary of the said transformer is connected to the RF source and wherein a decoupling capacitor, with a value being on the order of but not limited to 10 times the electrode set capacitance, is placed across the second resistor and second capacitor in series to complete the resonant circuit.

16. A device as described in claim 12 wherein the impedance network incorporates a current limiting function to prevent arc formation where the current limiting function is made of but not limited to a second inductor in series with a second resistor.

17. A device as described in claim 12, wherein the series resonance function may be accomplished by an inductor formed by physical characteristics such as but not limited to the shape of the electrodes themselves and where the series resistor may be provided by the electrical material resistivity and shape characteristics of the electrodes themselves such that no discrete resistor or inductor circuit elements are used to provide a resonant electrode function.

18. A device as described in claim 2, wherein the electrodes capacitance described above is resonated in parallel mode using the said first inductor and resistor in series with a decoupling capacitor placed across the electrode capacitance, said decoupling capacitor value being on the order of but not limited to 10 times the electrode set capacitance, the

current limiting function provided by the second inductor and resistor being by passed by another decoupling capacitor to complete the resonant circuit.

19 A device as described in claim 4 wherein

- the surfaces of the electrodes are fitted with numerous conductive ``peaks``, electrically connected to the electrode surface and distributed over the electrode exposed surfaces, and
- said peaks being but not restricted to triangular, rectangular, square and polygonal shapes, and
- the exposed edges of said peaks having also secondary peaks along their exposed sides and where all the peaks are made sharp along their edges and tips, and
- said surfaces of said peaks are being aligned parallel with the air flow to minimize the flow restriction and pressure drop across the device, and
- these peak shapes being also of a conical shape, a pyramidal shape, a polygonal volume shape, a cylindrical needle shape, a polygonal cylindrical shape or an arbitrary elongated volume shape generated by the rotation of a flat asymptotic curve and or a combination of these above shapes where all these shapes have sharp edges and/or tips.

20. A device as described in claim 4 having a first stage, but not limited to one, formed by an electrode set of planar geometry wherein all the electrodes are transparent with respect to the air flow, and where the electrode surfaces are all placed perpendicular to the airflow and wherein the inner transparent electrode increases the lifetime of the ionized contaminants by making the ionized contaminant to oscillate through the inner electrode due to the opposite electrical field on each side of the inner electrode and wherein a negative potential on the inner electrode will make the positive ions to oscillate

through while a positive potential on the inner electrode will make the negative ions to oscillate through the inner electrode.

21. The device of claim 20 wherein the first stage electrodes are conductive and highly transparent with regards to the airflow such as but not limited to electrodes made of conductive wire grid, wire mesh, or perforated sheet metal.

22. The device of claim 21 wherein the first stage electrodes shape is preferably square, rectangular or circular or any other shape to fit a particular air distribution duct geometry.

23. The device of claim 20 wherein a second stage, but not limited to one is formed by a set of planar geometry electrodes and wherein the central electrodes are transparent and wherein the outer electrode surfaces are solid and light reflective and wherein all the electrode surfaces are being placed parallel to the airflow, each of these electrode sets being fed by a specific voltage waveform.

24. The device of claim 23 having at least a second stage where the electrode characteristics are conductive and highly reflective to light such as but not limited to polished metal or alloy, or metallic plated composite material.

25. A device having a set of three electrodes of planar geometry and having their surfaces placed perpendicular to the airflow as in claim 20 where the electrode set is composed of a first subset of two electrodes of planar geometry having peaks only within the two electrodes and placed upstream from the airflow and where the most upstream outer electrode is feed by a high voltage waveform through an impedance matching network, having resonance and current limiting functions, and where the inner electrode is now connected to the other waveform terminal, the most downstream other electrode forming a second subset that is electrically conductive, transparent and has smooth surfaces without any peaks, the second subset of electrode being connected to a DC power supply

and the DC power supply being reference to the potential of the first subset electrode located downstream of the airflow, the voltage waveform applied to the first subset of electrode being limited to negative polarity and the DC supply being positive with respect to the second subset of electrode, alternatively the polarity of the waveform together with the polarity of the DC supply may be inverted, the down stream electrode surface finish is such that that the local electrical field at its surface will not extract electrons to be accelerated toward the first subset of electrodes.

26. A device according to claim 25 having a third stage, but not limited to one, formed with two or more electrodes of planar geometry wherein the electrodes do not have peaks but are smooth and may be coated with a dielectric material such that they will not emit electrons and wherein said electrodes are preferably made of sheet metal with the dielectric enclosing the electrode conductive surfaces, and wherein all the electrode surfaces are placed parallel to the airflow, said electrodes being fed with a specific DC high voltage to create an electrical field that will attract the charged by-products. and wherein the electrode surfaces exposed to the airflow are made intentionally rough and porous in order to capture and retain the electrically charged by-products of the previous stages.and wherein said stage is built in such a way that it is easily accessible for cleaning or replacement.

27 The device of claim 26 wherein a dielectric coating is used, the dielectric having an intrinsic high leakage resistance to dissipate the accumulated surface electrical charges, and wherein said resistance value is sufficient so that the net accumulated charges on the dielectric surface do not reduce significantly the electrical field.

28. The device of claim 27 where the dielectric is a porous chemical substance itself or the dielectric is coated with a chemical substance to react with and transform the by-products.

29. The device of claim 19 wherein the electrodes can be made of plastic or composite material plated or deposited with a thin conductive metal finish such as but not limited to zinc or nickel or aluminum or a combination of different metals that can be deposited in solution, plated, flame sprayed or vaporized by an heat source on plastic or composite surfaces.

30 The device of claims 24 and 26 wherein stages 2 and 3 have their electrodes set of cylindrical geometry.

31. The device of claim 30 wherein stages 2 and 3 have their electrodes set of polygonal shape and preferably but not limited to a hexagonal shape.

32. The device of claims 24 and 26 where the different electrode sets for stage 2 and 3 configurations are stacked to accommodate a larger airflow and or to reduce pressure drop in the device by increasing its cross section.

33. The device of claim 8 having an integral blower or ventilator or compressor to move the air through the processing stages.

34. The device of claim 8 wherein the arbitrary high voltage or current waveforms supplying the different stages has the following specific parameters: different controlled amplitudes for positive and negative cycles different rise and fall times for positive and negative cycles, different amplitude on times for positive and negative cycles and different off time following the positive and negative cycles.

35. The device of claim 34 wherein a DC voltage or current component may be added to the waveform.

36. The device of claim 34 wherein the waveform is continuously repeated over time.

37. The device of claim 34 wherein the waveform is repeated over time using at least one, but not limited to one, different set of parameters for the positive and negative cycles and where this newly obtained waveform is repeated continuously to create over time a multiplicity of electrons average controlled energy levels.

38. The device of claim 34 wherein the waveform has specific peak amplitudes for both polarities such that the electrons, through the established electric field, are acquiring a specific average energy distribution that match the desired chemical bonds energy levels to be ruptured or damaged and also avoiding energy levels that will generate undesirable or harmful by-products such as but not limited to ozone and nitrogen oxides.

39. The device of claim 34 wherein the waveform has an alternating polarity over time at a specific frequency.

40. The device of claim 34 wherein the waveform has specific rise and fall times and/or specific time derivative of the voltage waveform to restrict undesirable ionization energy levels,

41. The device of claim 34 wherein a part of the voltage or current waveform has a rich spectral content at the resonant radio frequency (RF) circuit formed by the electrode capacitance and the resonant impedance network.

42. The device of claim 34 wherein the waveform has a specific AC frequency that is preferably selected at the acoustical cavity resonance frequency formed by the electrode geometry and/or the device enclosure to generate resonant phonons.

43. The device of claim 34 wherein the waveform has a specific AC frequency that will by nature, when the frequency is low enough, automatically extinguish an electrical arcing condition between the electrodes.

44. A device according to claim 34 having a fourth processing stage that is made of conductive parallel wires or wires grid or wires mesh plated or coated with a catalyst material such as, but not limited to, platinum foam to remove and or neutralize the remaining ions and undesirable by-products such as but not limited to ozone, said conductive parallel wires or wires grid or wire mesh being referenced to ground for electrical charge dissipation.

45. The device of claim 44 where the parallel wires or the wires grid or the wire mesh have an electrical AC or DC current, supplied by the controller, circulating through them to increase significantly their surface temperature for improved catalyst conversion efficiency.

46. The device as described in claim 8 having a controller that generates the various high voltage waveforms required by the different stages, reads and processes the sensors information part of the device such as but not limited to: the differential input-output pressure, the absolute pressure, the temperature, the various stage currents and voltage waveforms and the light emitted by the current discharge in the various stages and where one or more or a combination of sensors information are used to control the device and issue operational status of the device to the user(s) or the operator(s).

47. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the differential pressure is above a pressure P1 or below a pressure P2 where P1 and P2 are two preset differential pressures and wherein , under such malfunction, the various high voltage stages may be turned off by the controller and wherein two specific warnings may be issued to signal to the operator(s) or user(s) that

the device may be clogged if the differential pressure is too high (above P1) or that the airflow is insufficient if the differential pressure drops below a certain minimum (below P2).

48. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the device absolute pressure is above a pressure P3 or below a pressure P4 and wherein P3 and P4 are two preset absolute pressures, and wherein, under such malfunction, the various high voltage stages may be turned off by the controller to prevent any possible further breakdown if the absolute pressure becomes too low (below P4).

49. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the device and/or the air temperature being processed is above a temperature T1 or below a temperature T2 where T1 and T2 are two preset temperatures and wherein, under such malfunction, the various high voltage stages of the controller may be turned off and wherein a specific extra warning may be issued to signal to the operator(s) or user(s) that the air temperature is too high and that there is a possibility of fire or malfunction of the system.

50. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the measured various stage voltage waveforms WVn at the electrodes are above a corresponding preset reference waveforms WV1n and/or below a corresponding preset reference waveform WV2n where the index n corresponds to a particular stage and wherein, under such malfunction, the various high voltage stages may be turned off by the controller.

51. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the measured various stage currents waveforms WIn of the electrodes are above a corresponding preset reference waveforms WI1n and/or below a corresponding

preset reference waveform WI2n where the index n corresponds to a particular stage and wherein, under such malfunction, the controller may turn off the corresponding or all the various high voltage stages and wherein if the measured current waveform is above the reference waveform WI1n, the controller shall count this over-current occurrence by incrementing a counter Counter-n, reset a corresponding timer Timer-n, turn off the corresponding high voltage stage, wait for a preset period of time P1n and turn on again the corresponding high voltage and wherein, if the occurrence counter Counter-n becomes larger than a preset value V1n in the controller then all the device high voltage sources shall be turned off until the main power on the device is recycled, and wherein, if the occurrence Counter-n is below the preset value V1n and the Timer-n reaches the preset time value of P2n, then the corresponding high voltage stage shall be turned on again and the occurrence timer Counter-n and Timer-n shall be reset, and wherein, at power recycling, all the counters Counter-n and Timer-n shall be reset to zero .

52. The device of claim 46 wherein a malfunction warning is issued to the user(s) or operator(s) if the corresponding stage detected light level emitted by the corresponding discharge and measured with a photo detector having an optical response centered around a light wavelength WLn and having a bandwidth WBn is above a light level L1n or below a light level L2n, and wherein L1n and L2n are two preset light level intensities for the corresponding stage n and wherein, under such malfunction, the various high voltage stages of the controller may be turned off to prevent any possible further breakdown and wherein a too high light output may be an indication that an arc is taking place, whereas a too low level is an indication that sterilization of the air is not taking place.

53. The device of claim 52 wherein the photo detector used for a particular stage may be composed of a plurality of detectors, each of these detectors being centered at a different wavelengths and having a specific bandwidth corresponding but not limited to the desired and undesired ionization levels or dissociating energy photons for that particular stage and wherein this plurality of detectors is forming a specific group detector and

wherein the controller is thus imposing a different criteria on the detected levels of each or a combination of detectors within a group to determine if the sterilization process is taking place in that particular stage, said criteria being possibly, but not limited to, the presence of one or a combination of certain specific preset minimum intensities for each detector forming a group or the absence of one or a combination of certain specific preset maximum intensities for each detector within the same group .

54. The device of claim 45 wherein the heating current is monitored and a malfunction warning is issued to the operators or users if the current is outside certain preset limits.

55 The device of claim 1 that is connected to an existing duct system by means of a duct adaptor that incorporates a crude filter to remove large particles such as dust and fibers and also a largely perforated funnel to make the airflow slightly turbulent and flow directors, in front of each stage, to direct the air between the corresponding stage electrodes, said largely perforated funnel being of triangular, conical or pyramidal shape perforated with a multitude of holes of different diameters along its surfaces.

56. The device of claim 46 wherein the controller uses the absolute pressure and temperature readings to control the actual amplitude voltages of the waveforms WVn through a mathematical expression or a stored table to compensate for the air density changes that has an impact on the electronic current energy and intensity, this being important where the actual operating pressure and temperature may vary significantly from the standard sea level pressure such as applications in aircraft, spacecraft, submarine, etc, the waveform may be adjusted according to but not limited to the following relation:

WSn applied = (WSn0 at P0 and T0) X ((Pactual X T0) / (Tacual X P0))^K

where WSn0 is the voltage waveform at P0 and T0 for stage n, P0 is the sea level reference Pressure, T0 is the sea level reference temperature, Pactual is the measured air operating pressure, Tactual is the measured air operating temperature , WSn is the

applied voltage waveform to the electrodes corresponding stage n and where K is an exponent normally equal or close to one when the ratio of Pactual T0/TactalP0 is between 0.84 and 1.16,. for ratio outside that range K takes other values.

57. The device of claim 56 wherein the mathematical expression for the compensation is a polynomial expression or a ratio of two polynomials of order k and l, where k is the order of the numerator and l is the order of the denominator.

58. The device of claim 56 wherein said compensation using the pressure and temperature measurements may be modified to use either the pressure alone or the temperature alone is one parameter is maintained relatively constant over the operating conditions.

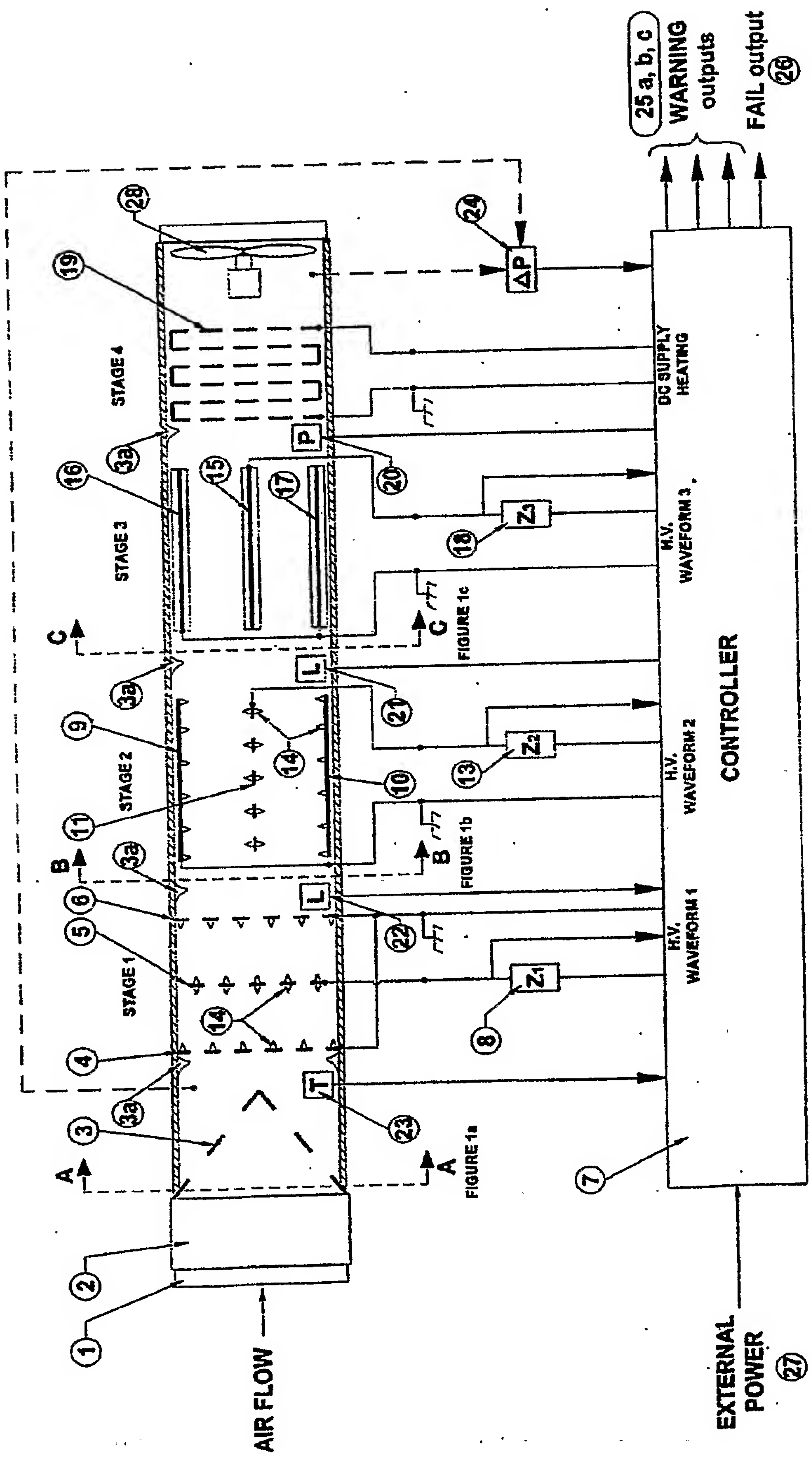

FIGURE 1
SYSTEM DIAGRAM

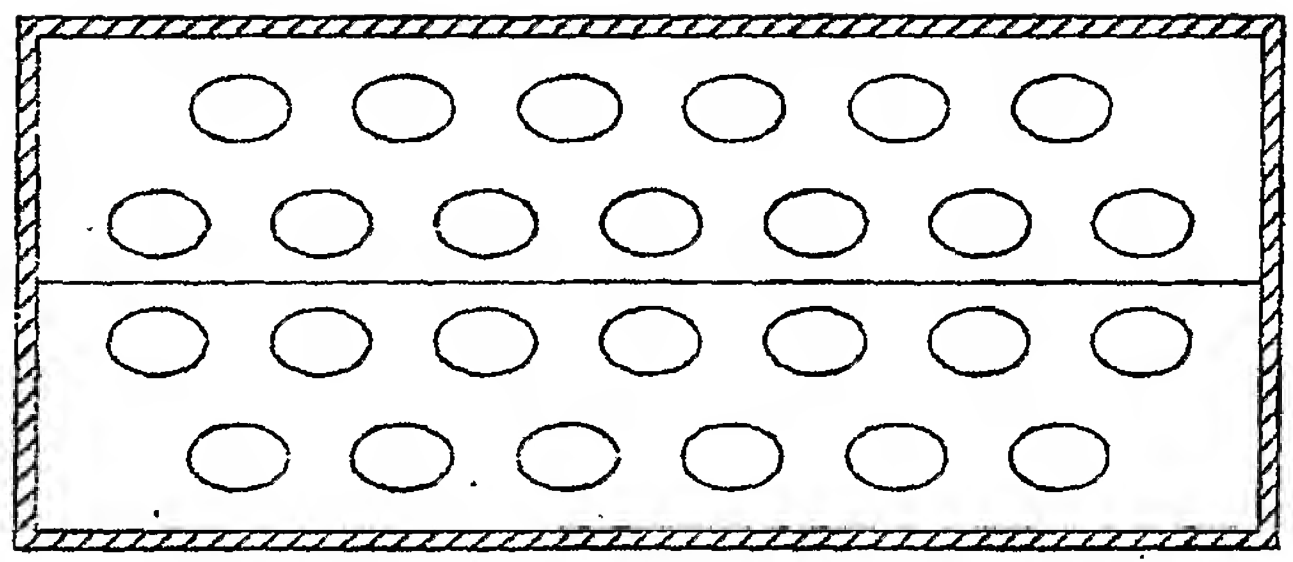

FIGURE 1a

View A

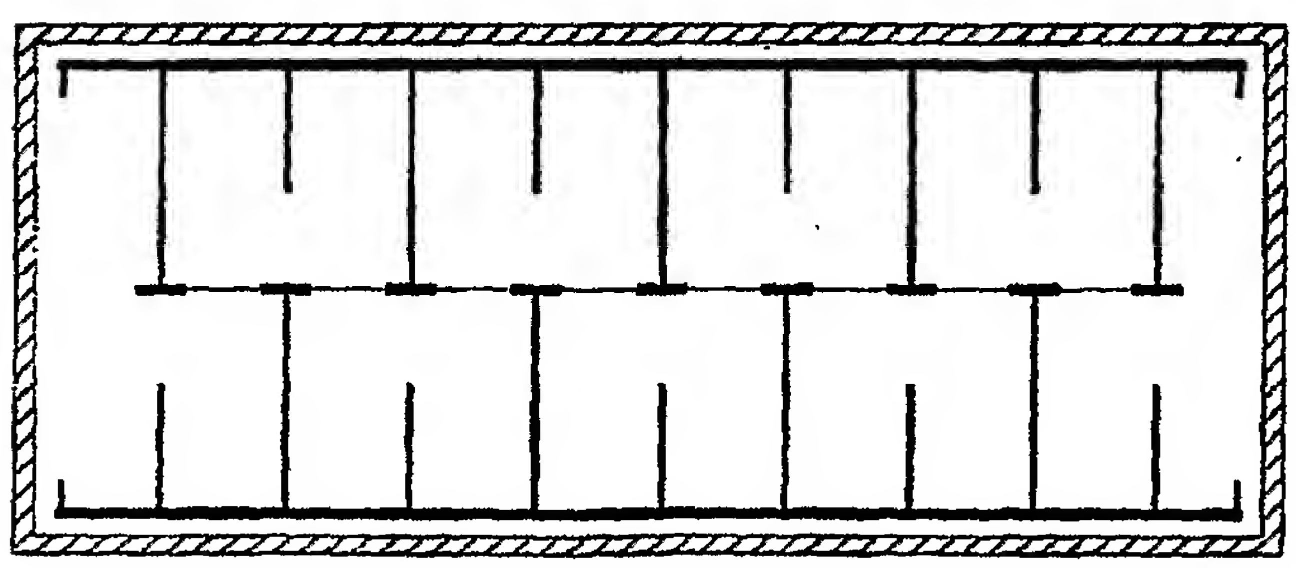

FIGURE 1b

View B

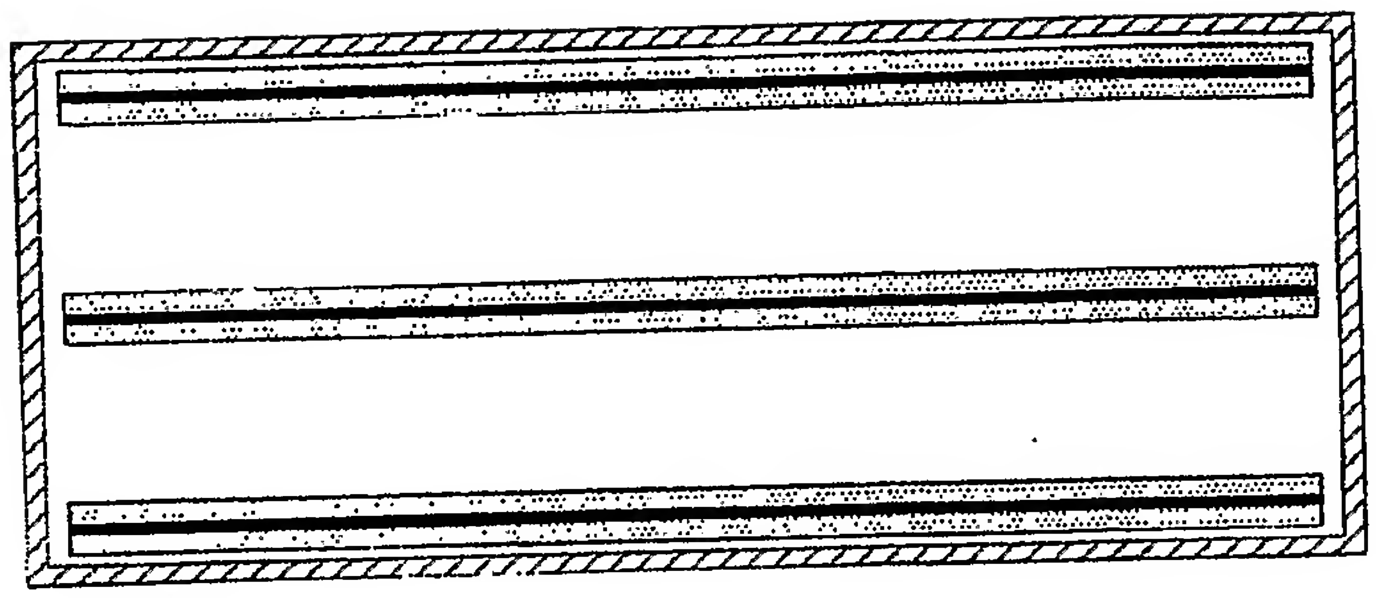

FIGURE 1c
View C

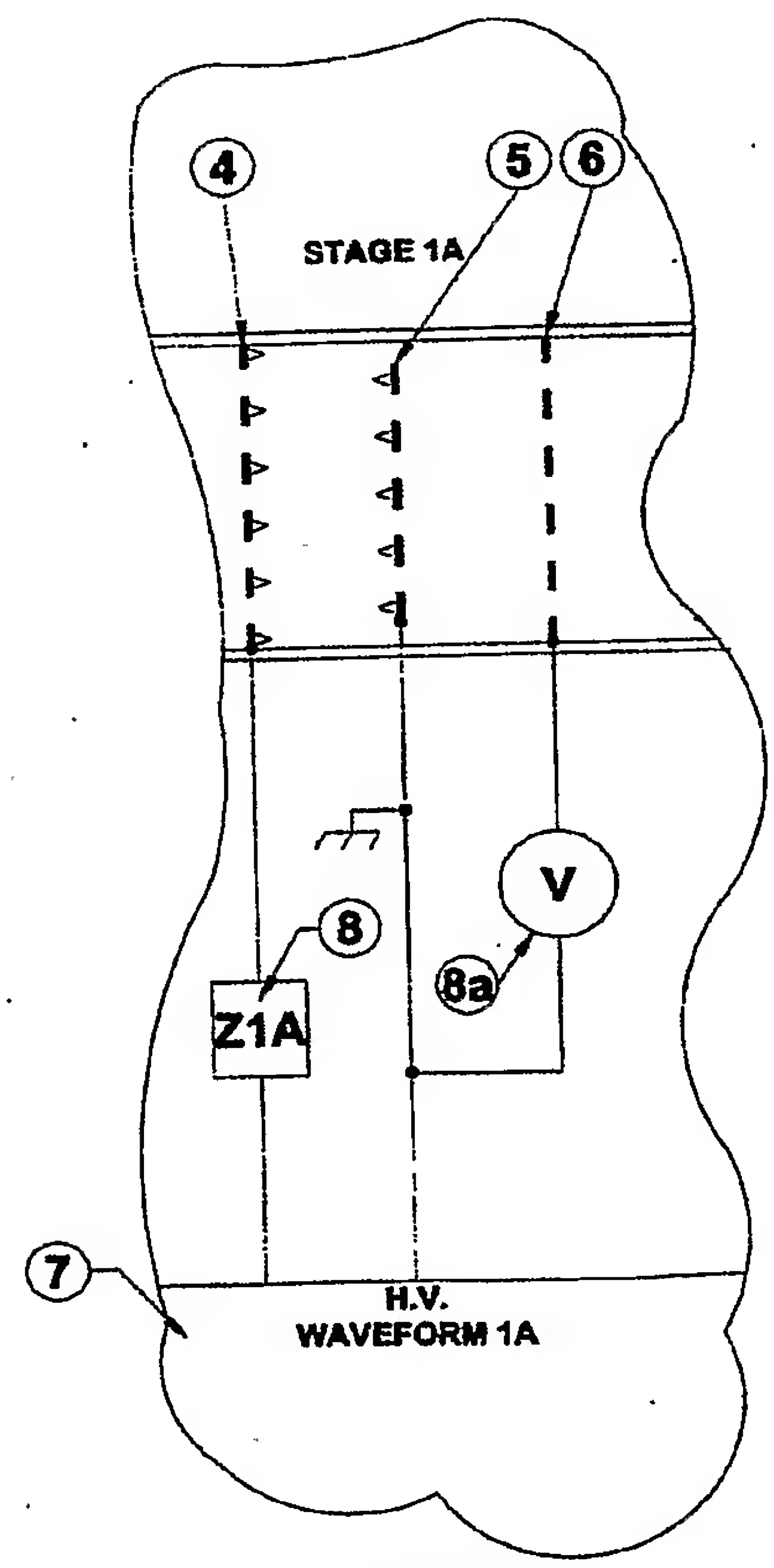

FIGURE 1d
STAGE 1A EMBODIMENT

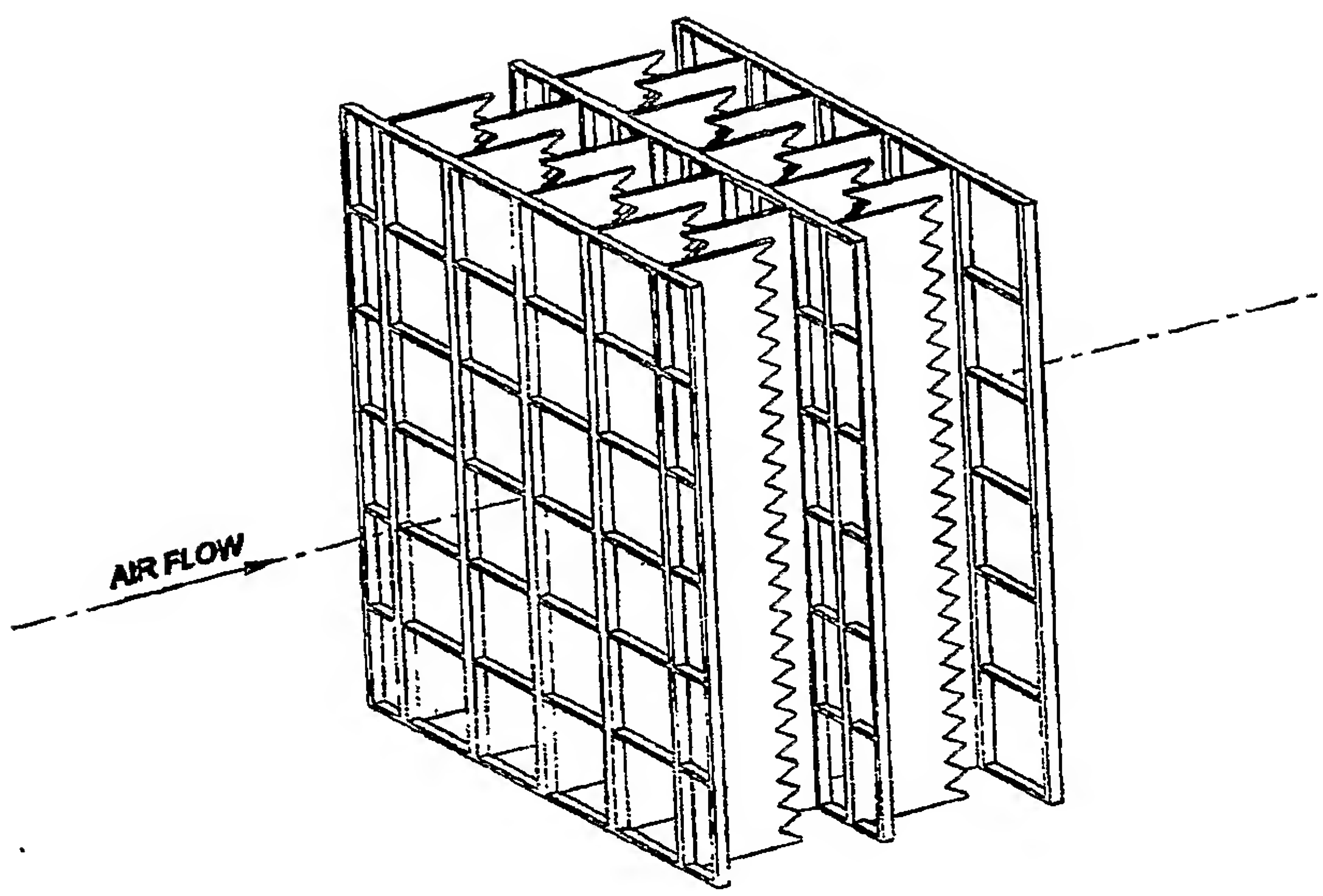

FIGURE 2
ELECTRODES & PEAKS EMBODIMENT
FOR STAGE 1 (1A)

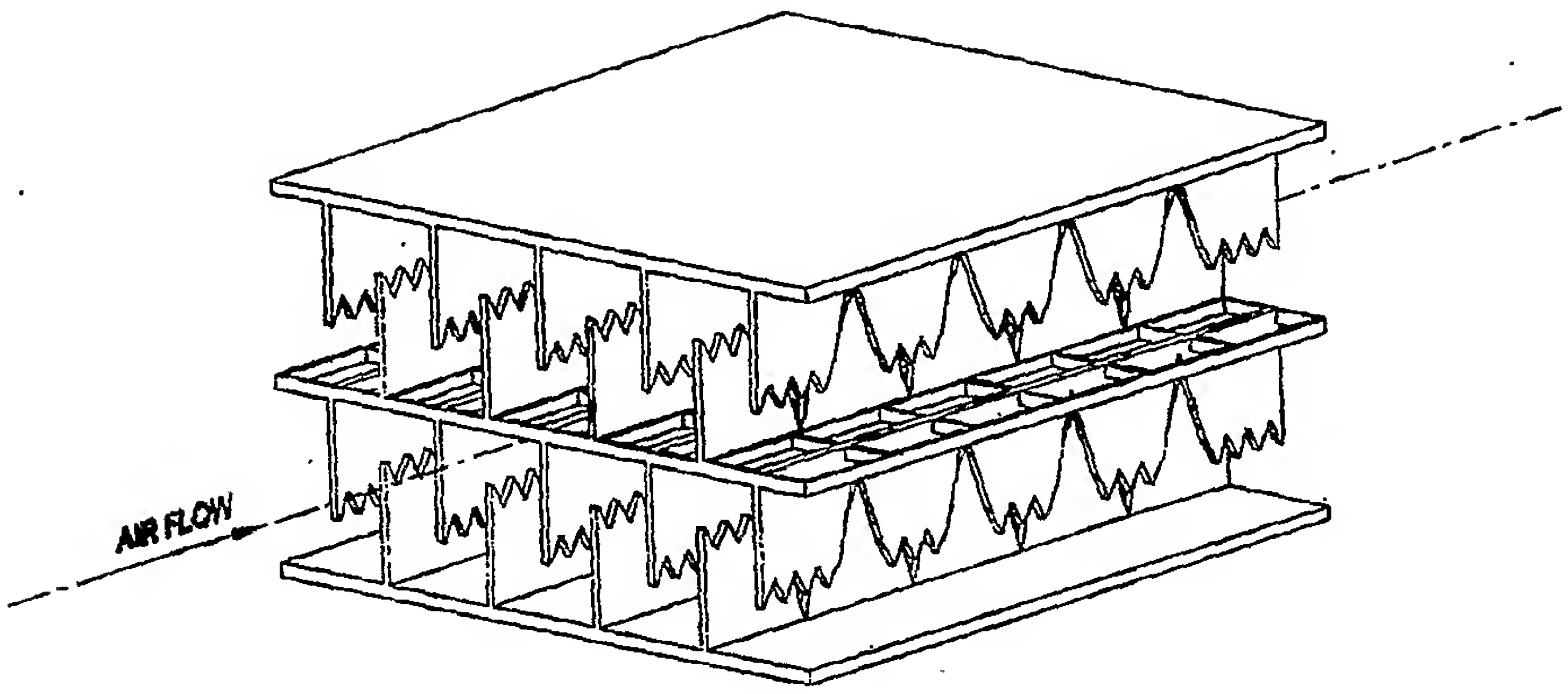

FIGURE 2a

ELECTRODES & PEAKS EMBODIMENT

FOR STAGE 2

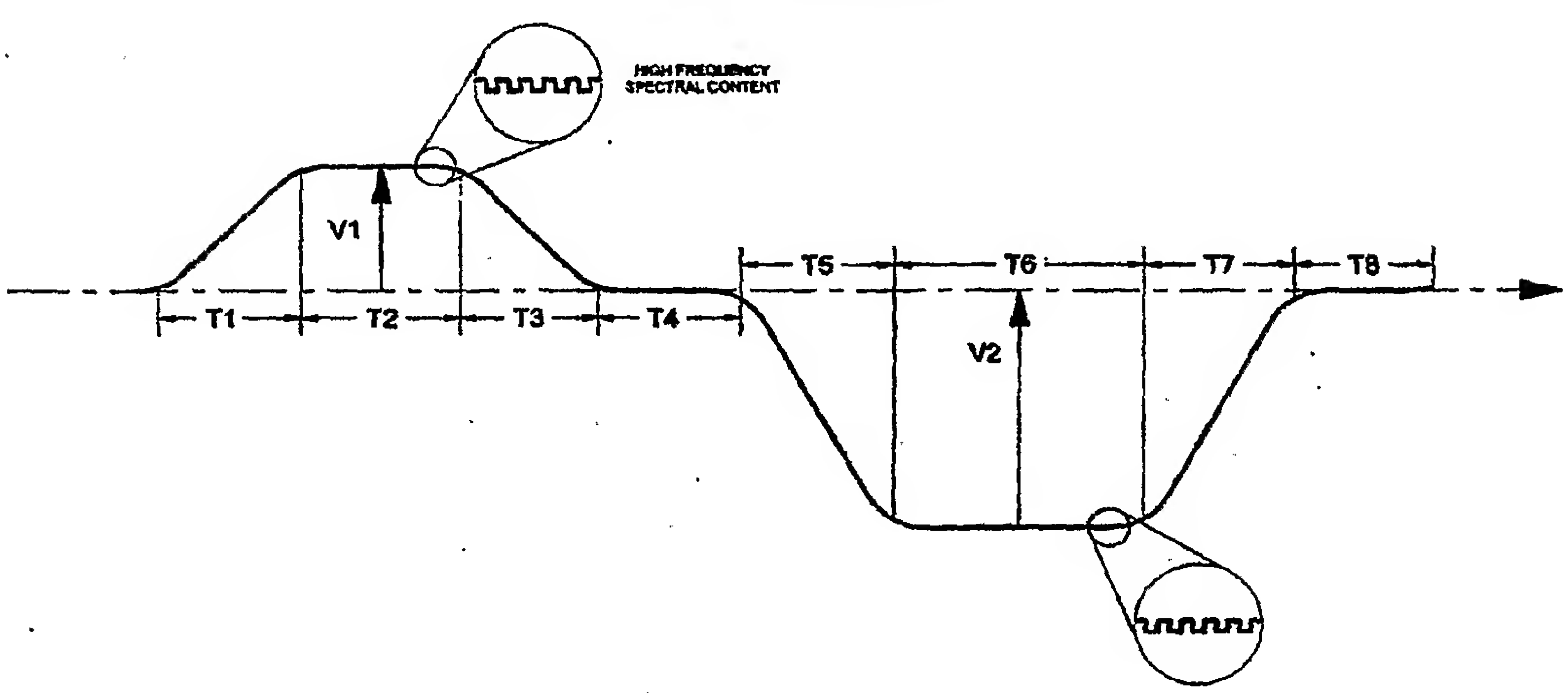

FIGURE 3

TYPICAL AC ARBITRARY

WAVEFORM FOR STAGES 1, 1A AND 2

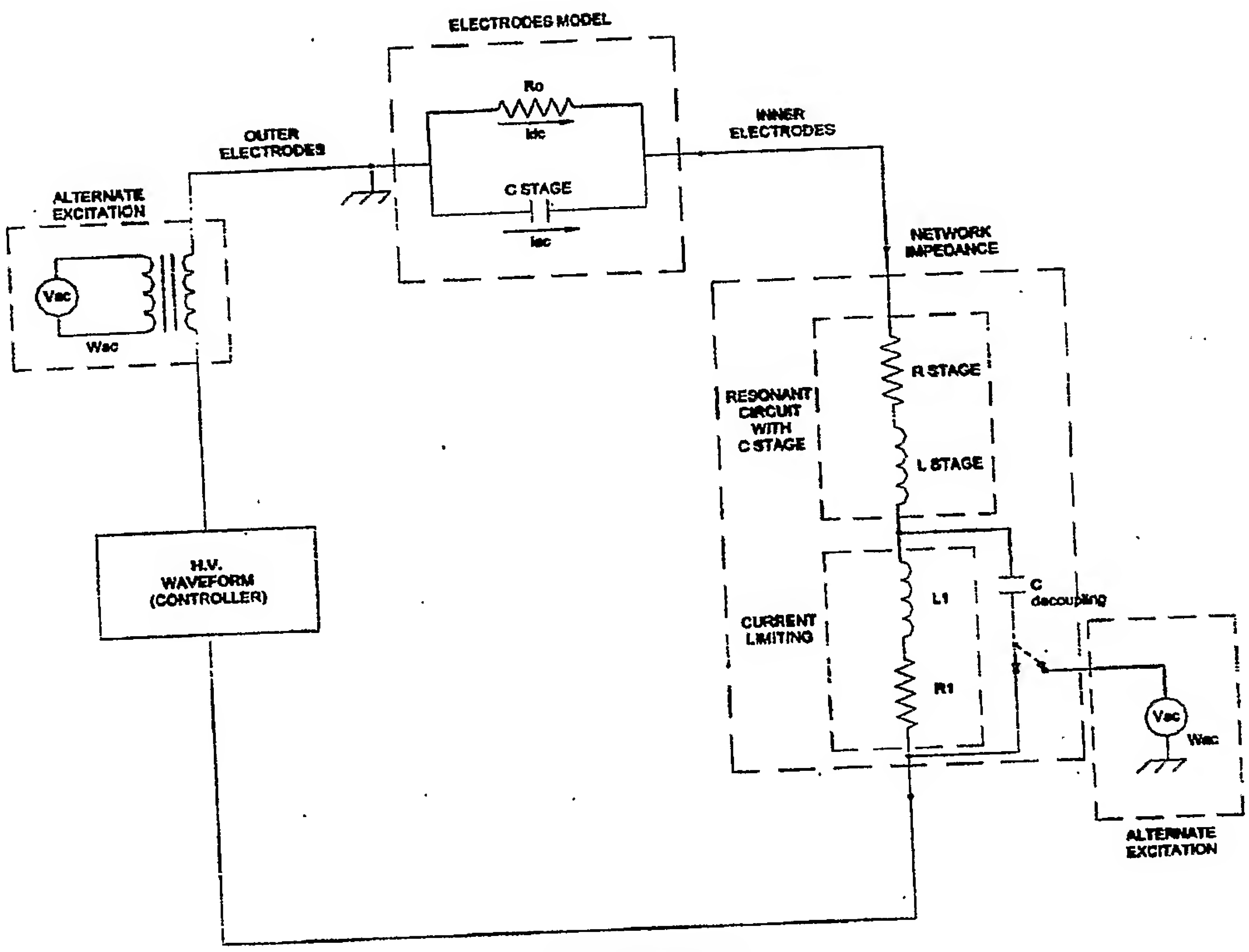

FIGURE 3a

NETWORK IMPEDANCE AND SERIES RESONANCE & EXCITATION

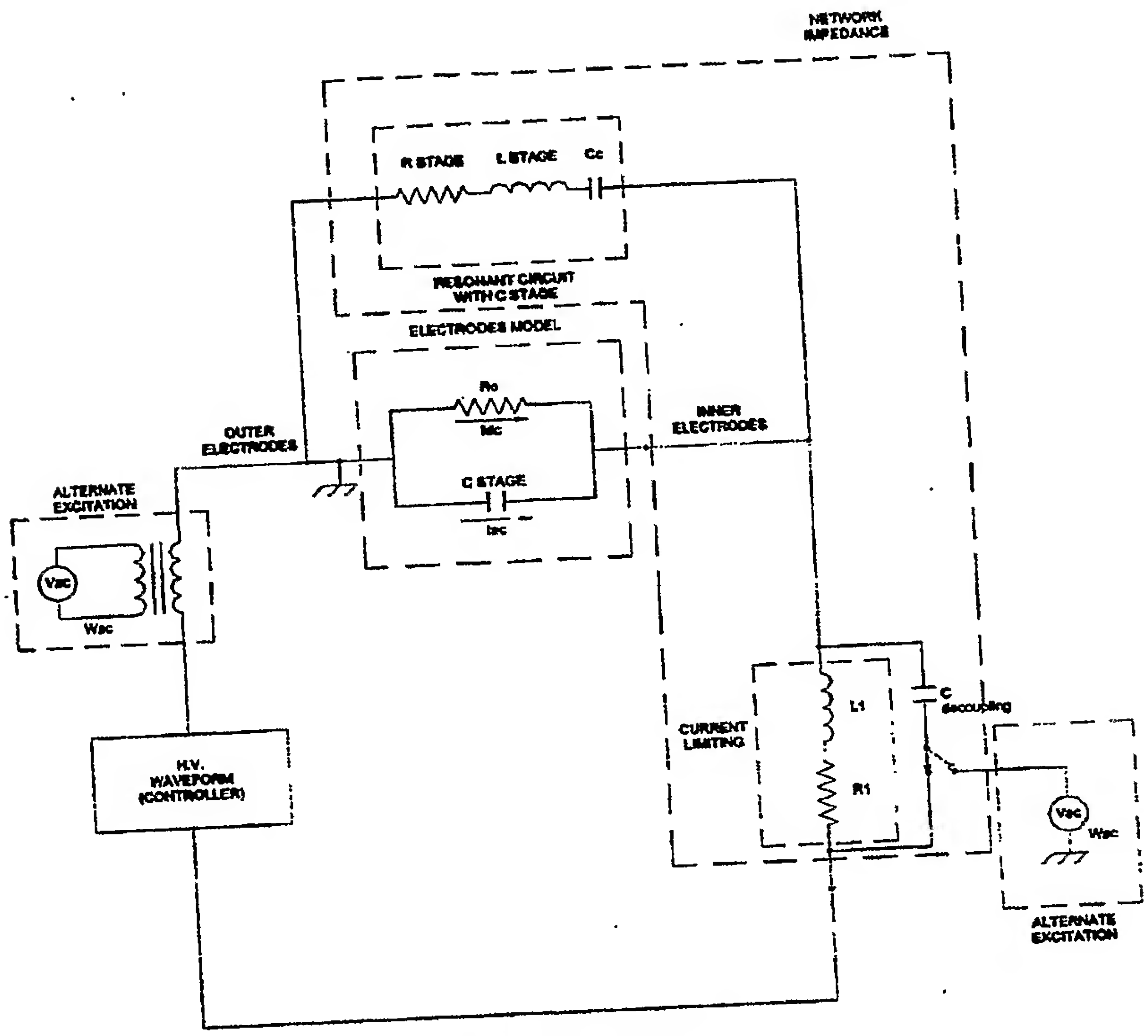

FIGURE 3b

NETWORK IMPEDANCE AND PARALLEL RESONANCE & EXCITATION

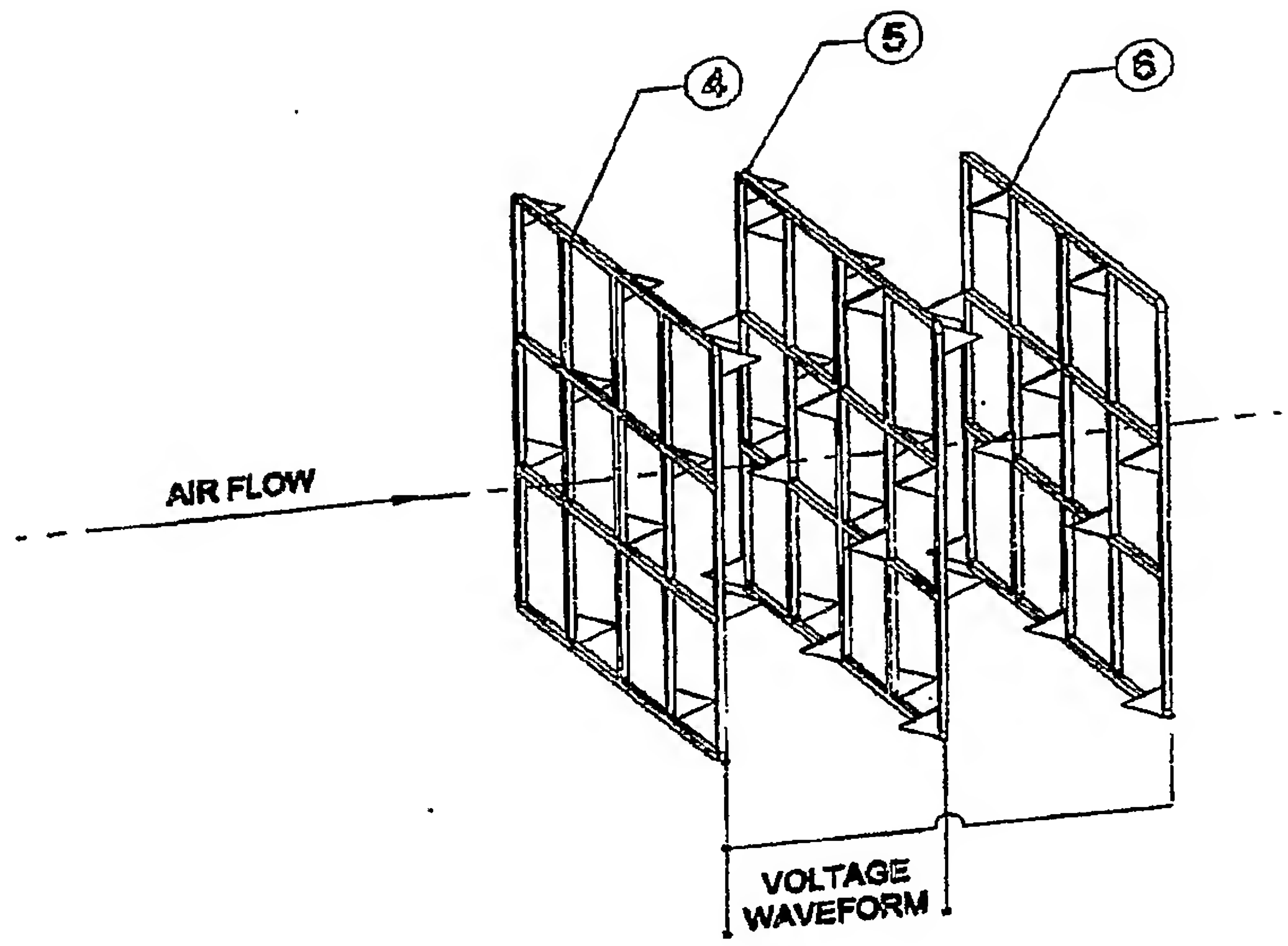

FIGURE 4
ELECTRODES PLANAR GEOMETRY
FOR STAGE 1 (1A)

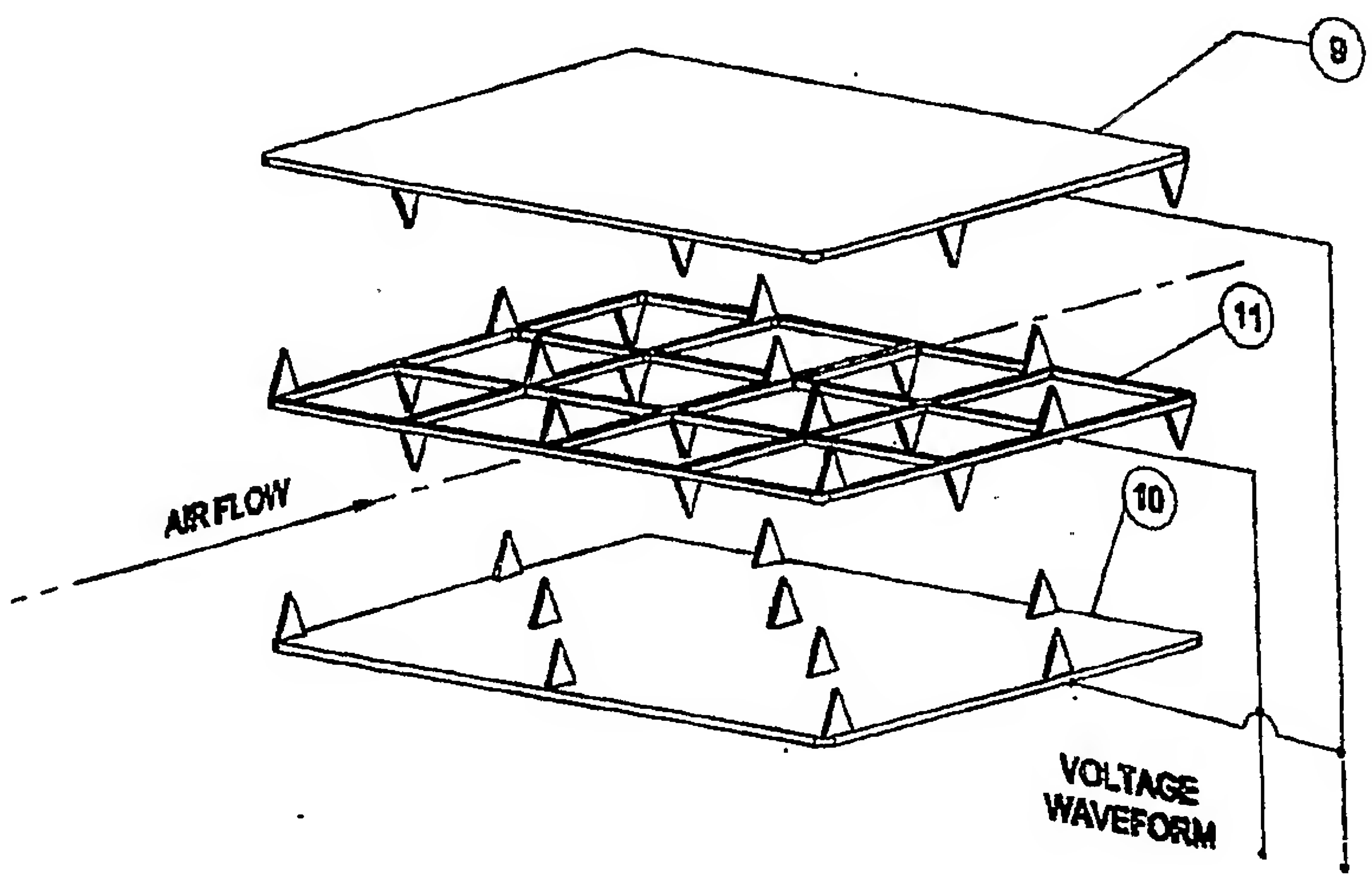

FIGURE 4a
ELECTRODES PLANAR GEOMETRY
FOR STAGE 2

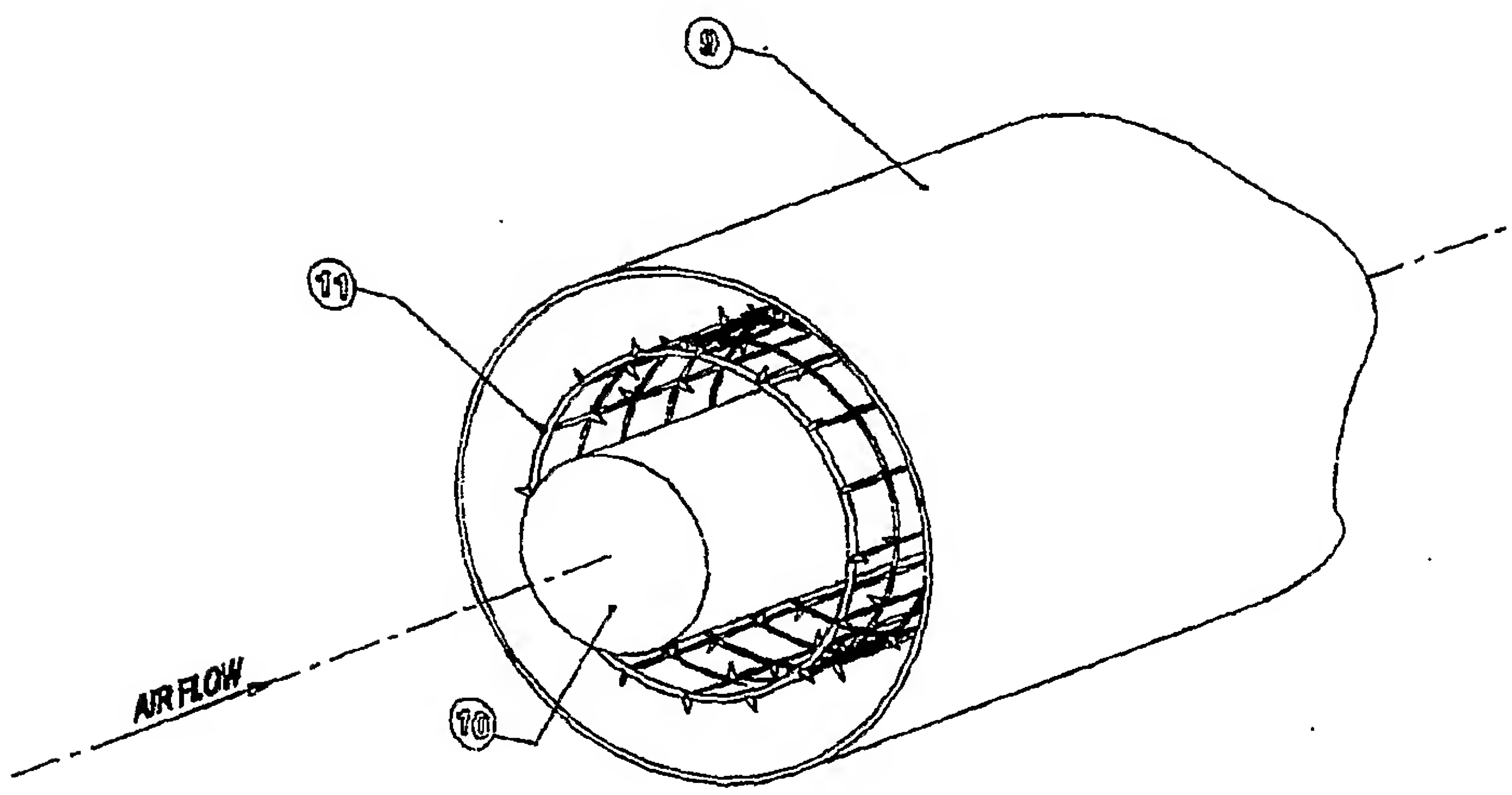

FIGURE 5
ELECTRODES CYLINDRICAL GEOMETRY FOR STAGE 2
(peaks on outer electrodes not showned)

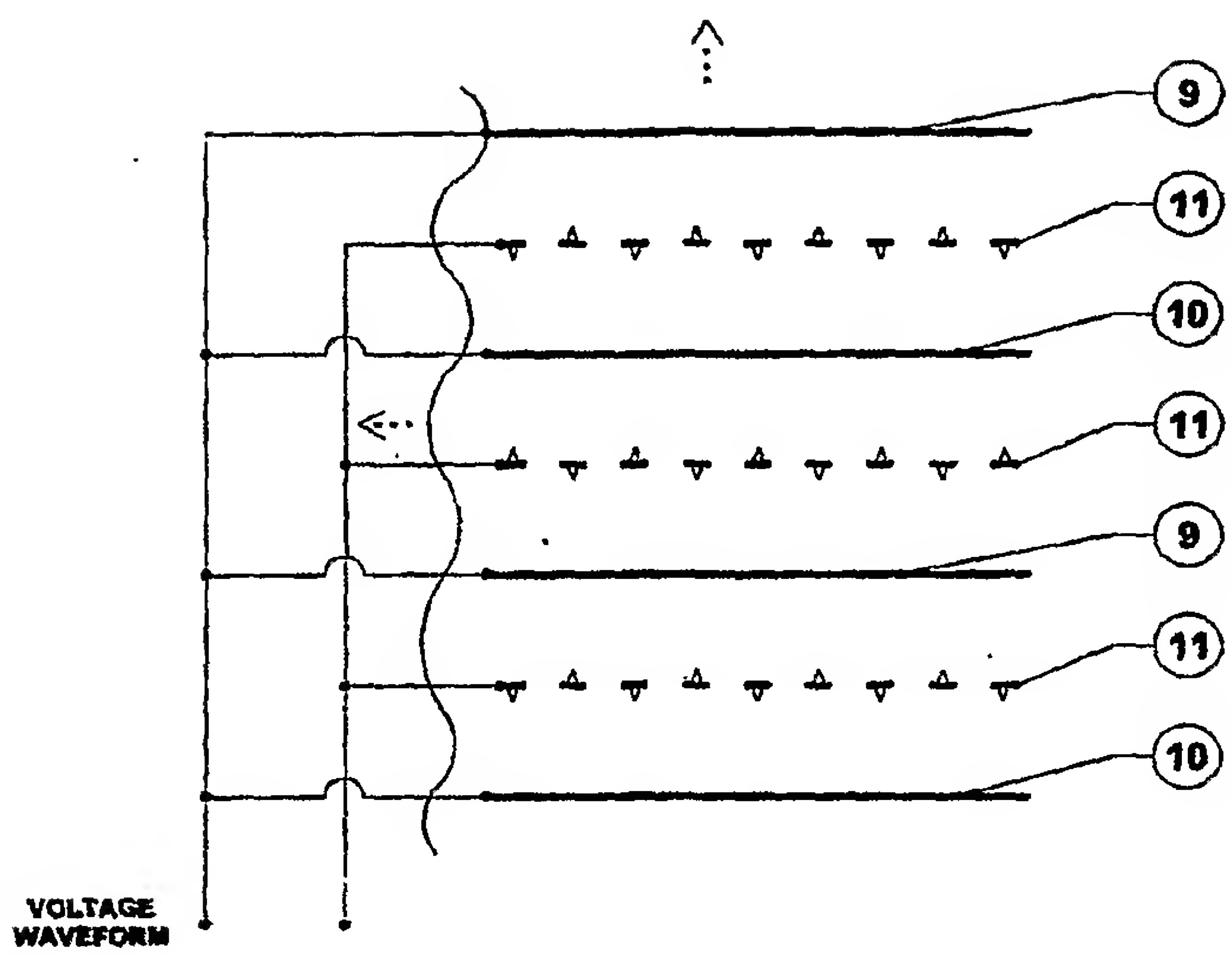

FIGURE 6

PLANAR STACKING

(peaks on outer electrodes not showned)

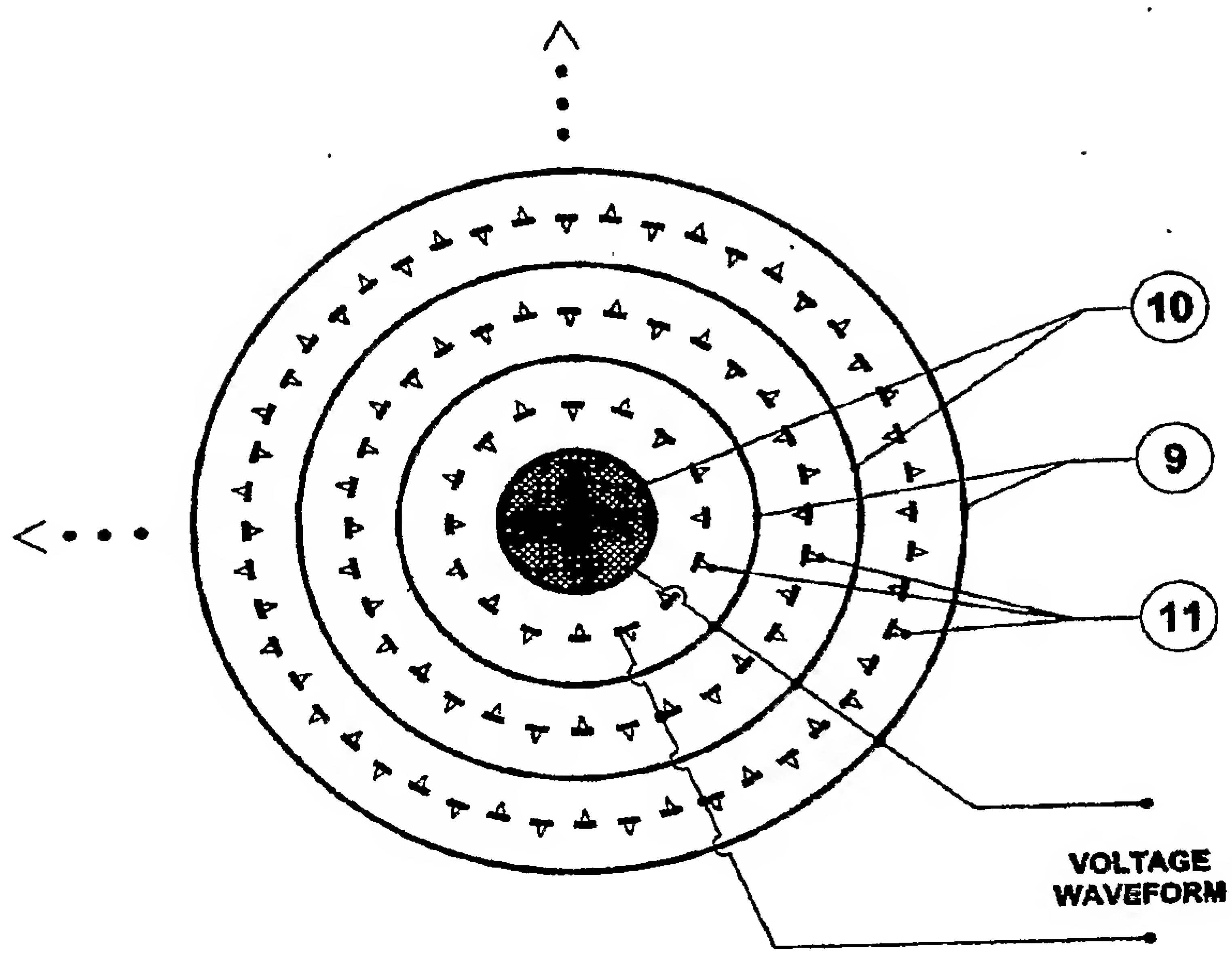

FIGURE 7

ELECTRODES CYLINDRICAL STACKING

(peaks on outer electrodes not showned)